



Run II Luminosity Upgrades

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Fermilab

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Outline

- Introduction
 - The Run II Upgrade Plan
- Current Status
 - Accomplishments
 - Technical Highlights
 - Project Status
- Scope of Work for FY05-09
- Performance Projections & Risk Analysis
- Summary

The Run II Upgrade Plan

Principal Elements



WBS 1. Luminosity Upgrades

- Increase antiproton production by increasing number of protons on the production target
 - ➔ 1.1 Protons on pbar target ($8E12$ ppp)
- Increase antiproton collection efficiency
 - Increase the gradient of the antiproton collection lens
 - Increase the aperture of the antiproton collection transfer line (AP2) and the Debuncher ring.
 - ➔ 1.2 Antiproton Acceptance
- Increase the antiproton stacking and storing capabilities
 - Increase the flux capability of the Accumulator stacktail stochastic cooling system.
 - Use the Recycler as a second antiproton storage ring
 - Transfer stacks of pbars from Accumulator to Recycler, periodically
 - Use both stochastic and electron cooling in the Recycler to maintain large stacks of antiprotons with desired beam properties.
 - ➔ 1.3 Antiproton Stacking and Cooling
- Upgrade Tevatron to efficiently handle higher intensity bunches
 - ➔ 1.4 Tevatron High Luminosity

WBS 2. Reliability Upgrades



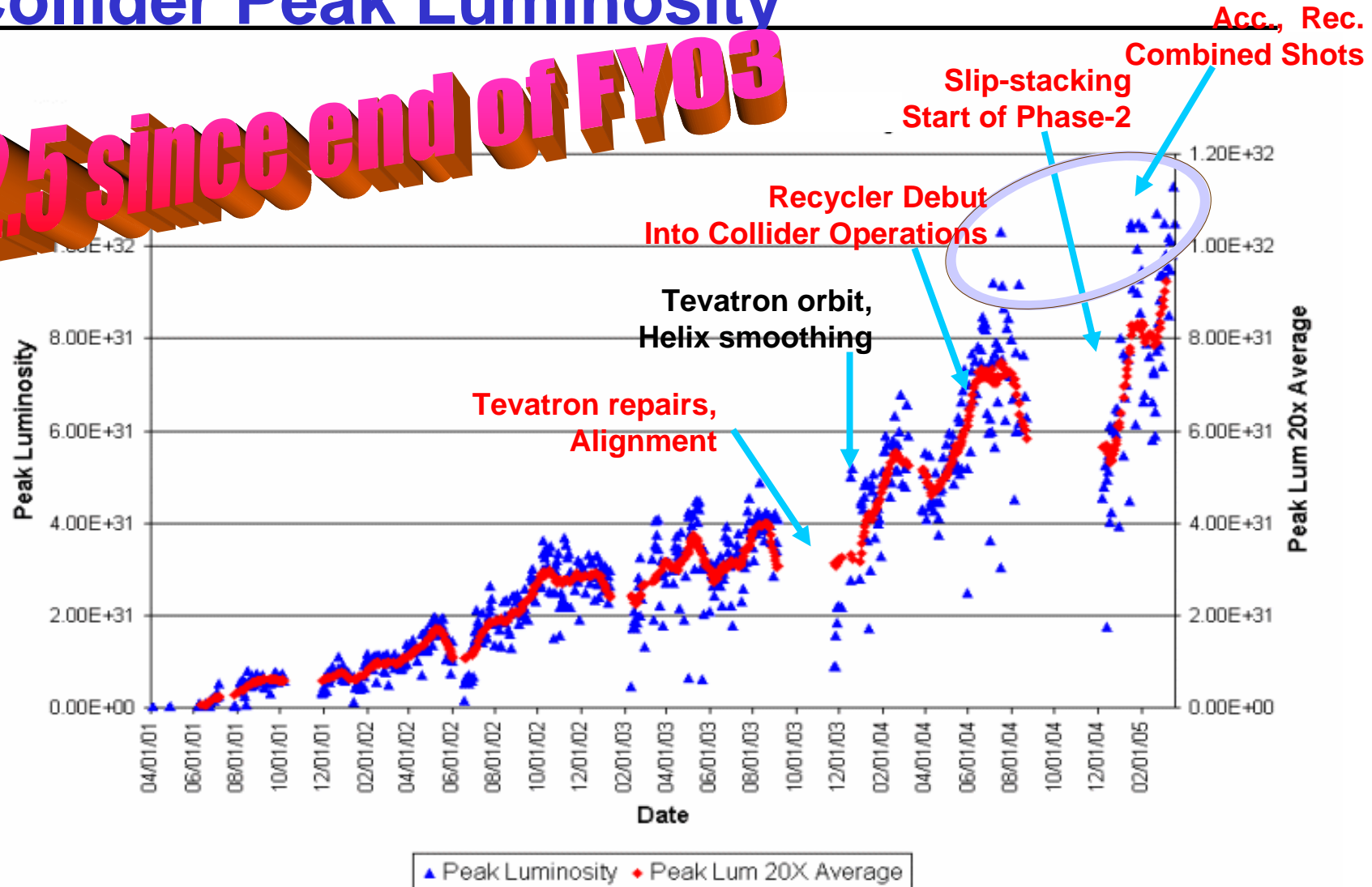
Major Accomplishments

- Upgrades hand-in-hand with operations
- Reliability Upgrades throughout the complex
 - Tevatron repairs/alignment, VFC card replacements, Linac tubes, Recycler Vacuum
- Operational Improvements
 - Tev helix, orbit smoothing, transfers between machines
- Luminosity Upgrades
 - Recycler commissioned & used as 2nd pbar storage ring
 - E-cool R&D completed; Installed in the Recycler
 - RF upgrades in MI completed and Slip-stacking commissioned
 - Instrumentation improvements made
 - **Started Phase-2 of Run II operations on schedule**

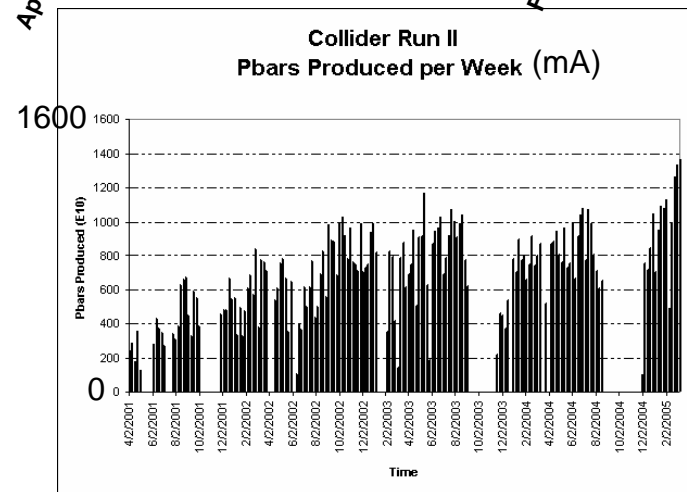
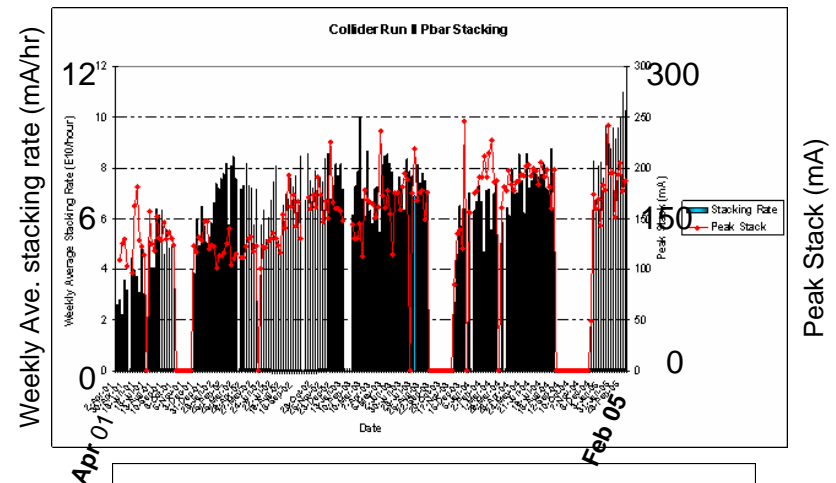
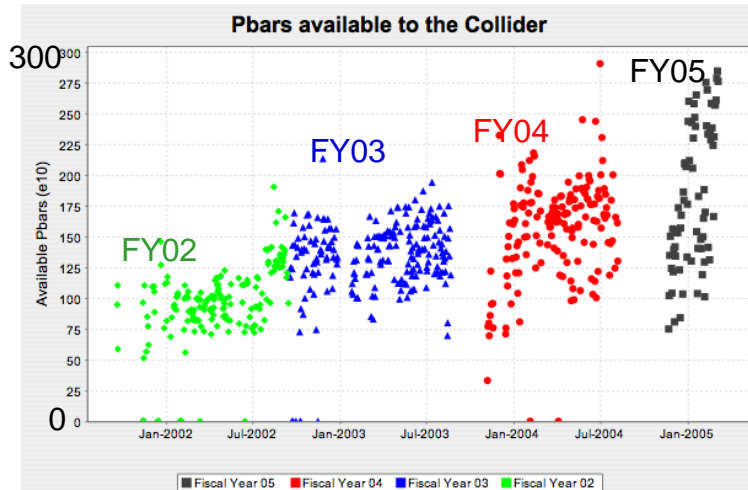
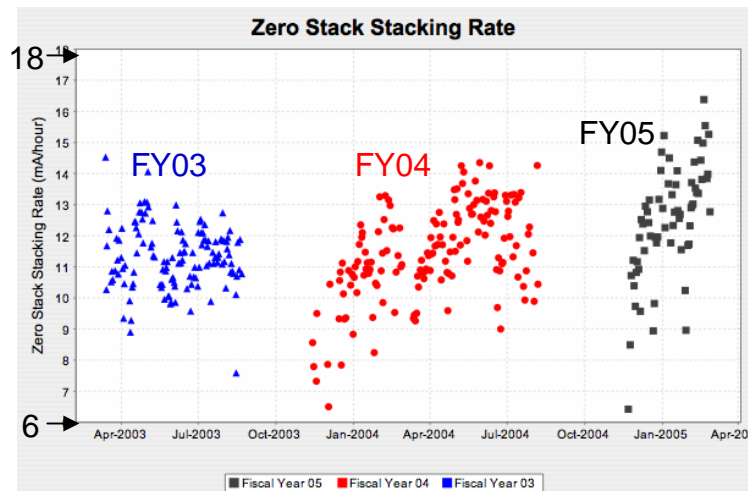
Run II Upgrades & Collider Peak Luminosity



x2.5 since end of FY03

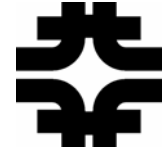


Antiprotons

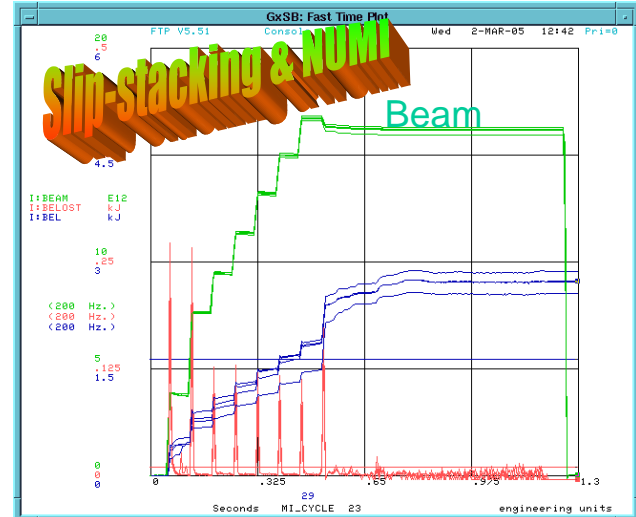
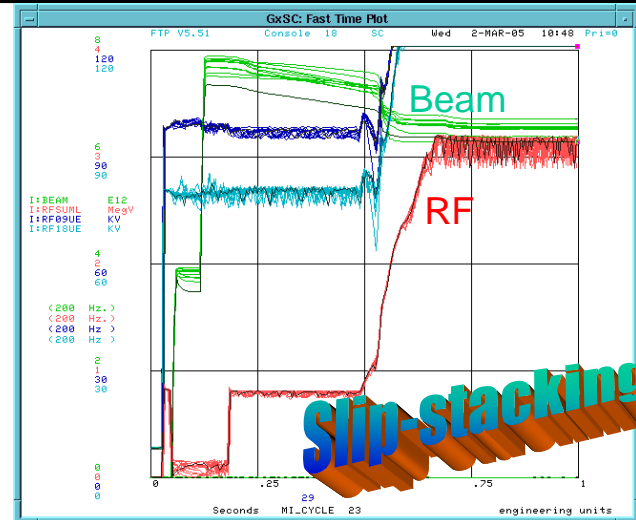
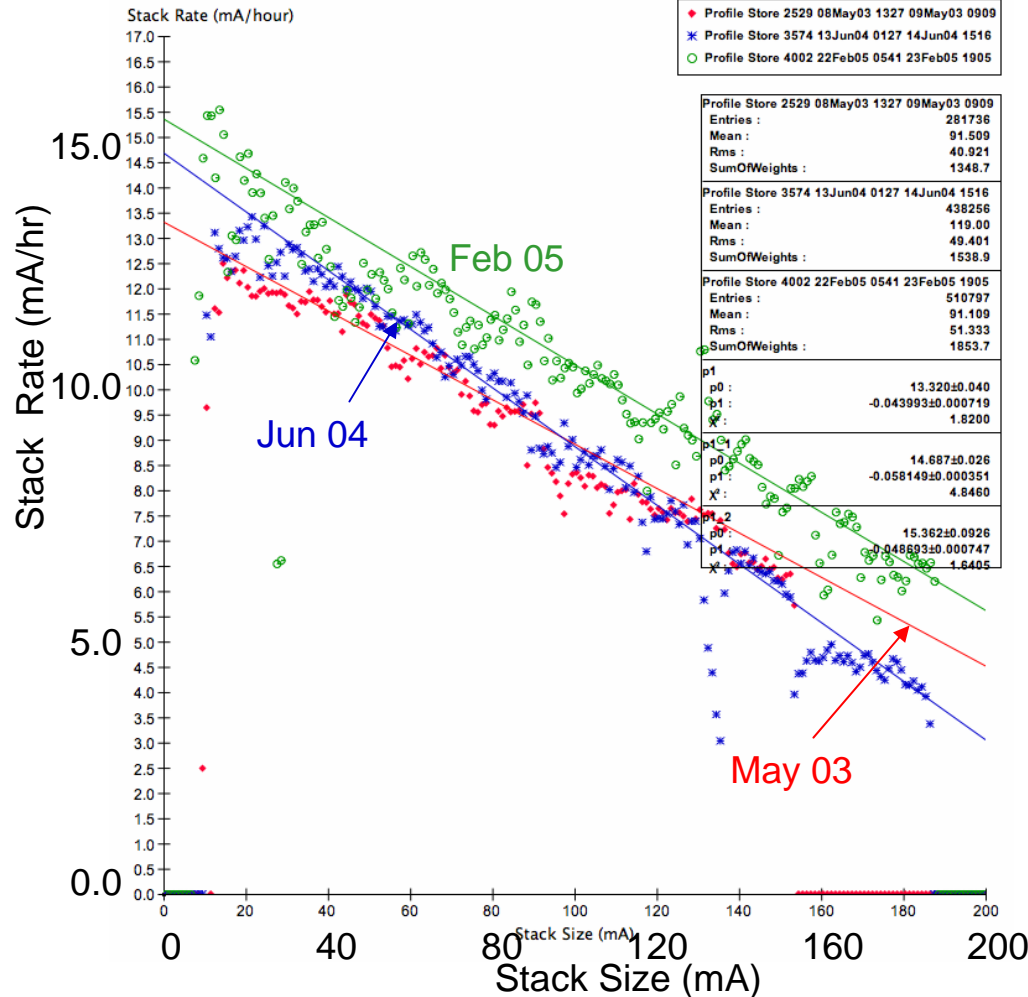


Technical Highlights

Antiproton Stack Rate

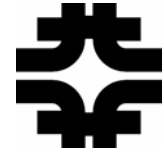


p1 - p1_1 - p1_2 - Profile Store 2529 08May03 1327 09May03 0909 - Profile Store 3574 13Jun04 0127 14...



Technical Highlights

WBS 1.1 Protons on Target



- All 18 RF stations in MI upgraded with beam-loading compensation
 - Slip stacking is operational with $>7E12$ ppb on the pbar production target (design goal: $8E12$ by end of FY05)
- 2.5 MHz pbar acceleration demonstrated, needs study time for commissioning
- Digital Dampers in MI commissioned and used in most modes of operation
 - Proton shots to the Tevatron, protons on target during stacking cycle, 2.5 MHz pbar injection
- New pbar production targets installed in July 2004
- OTR (Optical Transition Radiation) Detectors
 - Ready for installation soon – 2 in the AP150 beamline, 2 in the Tevatron in the vicinity of the IPM
- MI BPM
 - Work started; signal processing DDC boards in hand

Technical Highlights



WBS 1.2 Antiproton Acceptance

- **Lithium Lens**
 - New design complete; bench test of prototype-1 successful; expect to install before the '05 shutdown
- **AP2/DB/D→A Aperture Improvements**
 - '04 shutdown: installed motorized quad stands in DB, work on AP2/DB injection region, DB extraction bump magnets, eliminated some physical aperture restrictions
 - Lots of groundwork done
 - Instrumentation/diagnostics improvements
 - BPM and other diagnostics/tools upgrade progressing well
 - Position, intensity measurements becoming available throughout
 - developed/refined procedures
 - Small improvements in admittance seen
 - Found horz. Admittance largest with bump in DB extraction
 - Now commissioning ramping DB extraction bump
 - Study strategy changed to primarily use stacking cycles instead of reverse protons ← semi-parasitic instead of dedicated
 - Very promising, especially with new diagnostics and more affordable parasitic study time

See Breakout talk by Keith Gollwitzer

Technical Highlights



WBS 1.3 Antiproton Stacking & Cooling

- Recycler commissioned on schedule (June 1, 2004)
- pbar beam from Recycler selectively “momentum mined” for Tevatron shots (Ref.: C. Bhat, Physics Letters A 330, 2004, p481-486.)
- E-cool R&D completed at wide-band lab
- Installation of e-cool equipment in MI-31 and the Recycler tunnel complete
- Commissioning of electron cooling in progress

See Breakout talk by Sergei Nagaitsev



Technical Highlights

WBS 1.3 Antiproton Stacking & Cooling



- Stacktail system performing well with stack rates over 16 mA/hr
- Pick-up and Kicker tank designs for stacktail bandwidth upgrade finalized
- Planning tests for bandwidth upgrade, high intensity proton stacking studies and tests of reconfigured stacktail system during Fall 2005.
- Stacktail system upgrade to take place in 2 phases
 - Stacktail reconfiguration (easily reversible)
 - Bandwidth upgrade (not easily reversible)

More later

See Breakout talk by Paul Derwent

Technical Highlights

WBS 1.4 Tevatron High Luminosity

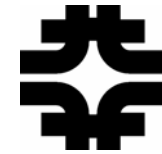


- Tevatron alignment & repairs
 - Re-shimming of dipoles, stand replacements, field measurements, alignment, monitoring system
- Helical orbits and separators
 - 2 additional separators and polarity switches installed in '04 shutdown and commissioned.
 - 15 -- 20% larger separation between p and pbar orbits
 - R&D on HV operation, electrodes in progress
- Active beam-beam compensation
 - Tevatron Electron Lens (TEL) R&D plan reviewed
 - TEL-2 being assembled and tested for installation in shutdown '05

See Breakout talks by Vladimir Shiltsev, Ron Moore, Yuri Alexahin

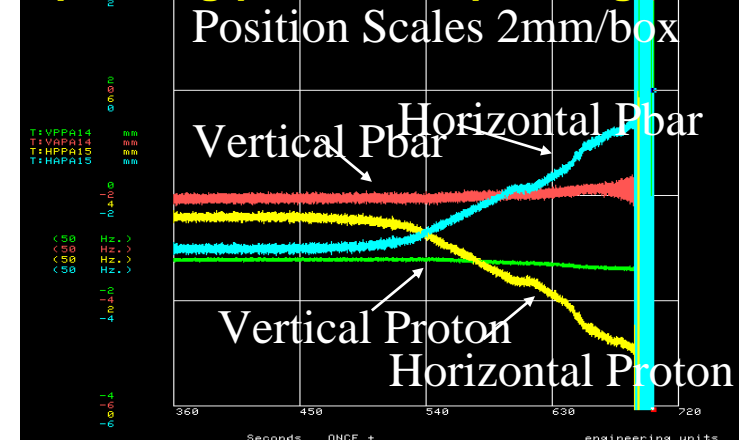
Technical Highlights

WBS 1.4 Tevatron High Luminosity

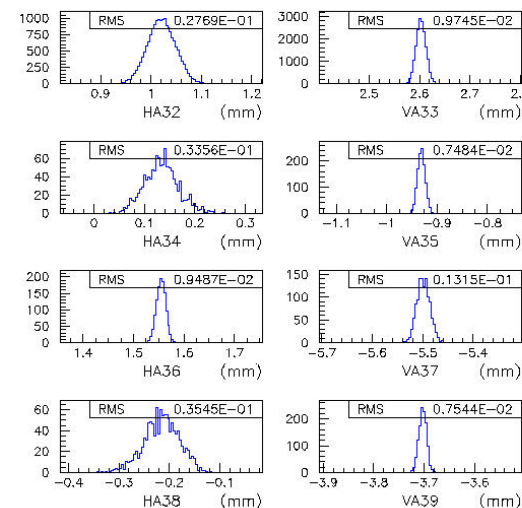


- Tevatron BPM Project
 - A major success
 - Project making very good progress though completion date has slipped to end of May '05
 - ← An order of magnitude improvement in proton position measurements and new capability for pbars
 - Position resolutions in the range of ~ 10 - 25μ
 - Will be extremely useful in understanding beams
 - Can see synchrotron and betatron lines, quadrupole oscillations, H-V coupling, etc.
 - $\sim 25\%$ of the installation complete
- See Breakout talk by Bob Webber

Separating proton and pbar signals



Resolution for A3 BPMs, Feb 14, 2005



Breakout Session Talks



Run II Operations & Upgrades

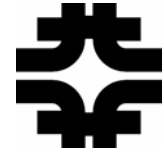
- Tevatron Operations (Shiltsev)
- Recycler Operations & e-cool commissioning (Nagaitsev)
- Rapid Transfers (Harms)
- Stacktail Cooling Upgrades (Derwent)
- Antiproton Acceptance (Gollwitzer)
- Tevatron beam-beam Issues (Alexahin)
- Tevatron Separators and Helical orbits (Moore)
- Tevatron Electron Lens (Shiltsev)
- Instrumentation Upgrades
 - BPMs (Webber)
 - BLM Upgrades (Lewis)
 - Tev Schottky (Jansson)
 - Tev Abort Gap Monitor (Thurman-Keup)



Project Status

- Regular reporting at monthly PMG
- Numbers here are from end of January Status report

Project Status



Actual and Planned % Complete at Level-2

WBS	Name	Actual %	Planned %	A/P %
0	Run II	62%	65%	96%
1	Luminosity Upgrades	64%	67%	96%
1.1	Protons on Pbar Target	73%	74%	99%
1.2	Pbar Acceptance	47%	52%	91%
1.3	Pbar Stacking & Cooling	67%	71%	94%
1.4	Tevatron High Luminosity	66%	68%	96%
1.5	Shutdowns	50%	50%	100%
1.6	Project Management	55%	55%	101%
2	Maintenance & Reliability	50%	51%	99%

Milestones Status



Uniq	WBS	Name	Finish	MS Class	2005											
					May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
2363	1.3.4.3.17	Recycler commissioned for Electron cooling	6/1/04	A	■											
2452	1.4.7.1.2	Review Tevatron Alignment Plans 2004 (Milestone)	8/2/04	C			■									
877	1.2.1.2.1.5	Prototype Lens 1: Completed (Milestone)	8/6/04	C			■									
919	1.6.5.3	Review e-Cooling Commissioning	8/10/04	C			■									
2361	1.3.4.3.15	Recycler Extraction Commissioned	8/19/04	C			■									
2005	1.4.5.4.4.1.3	First production quality crate Installation Begins	8/23/04	C			■									
94	1.5.3	Start Summer 04 Shutdown	8/23/04	C			■									
2446	1.3.3.1.3.2.1.4	Pickup array design finalized	8/31/04	C			■									
2447	1.3.3.1.3.2.2.4	Kicker array design finalized	8/31/04	C			■									
2545	2.2.4.2.11.2	Decision on 6U Crate	8/31/04	C			■									
1114	1.2.1.1.2.1	Decision on long lithium lens (Milestone)	9/15/04	C				■								
1952	1.4.5.4.3.1.1.1.6	Core electronics 1st production board available	9/27/04	C				■								
847	1.1.2.2.4.2	Beam Sweeping Ready (redefined)	10/21/04	A					■							
755	1.4.2.1.1.3	Review TEL R&D	11/10/04	C						■						
1526	1.5.4	Finish Summer 04 Shutdown	11/30/04	C							■					
1479	1.1.1.2.1.24	HLRF Upgrade complete	11/30/04	C							■					
1799	1.4.3.2.6	Polarity switches operational	12/1/04	C							■					
1831	1.4.3.4.3	New standard separators operational	12/2/04	A							■					
2441	1.3.3.1.3.1.2.3	Kicker tank design finalized	12/3/04	C							■					
852	1.2.2.10	Initial AP2&DB Improvements Complete (Milestone)	12/7/04	A							■					
2026	1.4.5.4.5.1.1	Begin system commissioning	12/8/04	C							■					
1490	1.1.1.4	Slip Stacking Operational	12/20/04	A							■					
1777	1.1.4.4	Booster-MI Cogging Operational	12/20/04	C							■					
920	1.6.5.4	Start Phase 2 (Milestone)	12/20/04	A							■					
2438	1.3.3.1.3.1.1.7	Pickup tank design finalized	2/1/05	C								■				
1995	1.4.5.4.3.2.3.2	Offline SW code complete	2/1/05	C								■				
898	1.3.5.5.22	Pelletron Installed at MI-31 (Milestone)	2/15/05	C								■				
1988	1.4.5.4.3.2.2.2	Online SW code complete	2/15/05	C								■				
1980	1.4.5.4.3.2.1.3	Frontend DAQ SW code complete	2/24/05	C								■				
1449	1.2.2.7.4	Decision to proceed with development of chromatic compensation	2/28/05	C								■				
3109	1.2.2.5.3.4.1.4	DB Ext. Kicker Decision to Proceed w/Upgrade	3/7/05	C								■				
1494	1.1.3.3.5	MI 2.5 MHz Acceleration complete	3/17/05	B								■				
2014	1.4.5.4.4.2.2	Tev BPM Frontend Integration Test Complete	4/25/05	C								■				
2009	1.4.5.4.4.1.7	All Tev BPM crates functionally available (except for F bldg.) or Installed	4/29/05	C								■				
2030	1.4.5.4.5.1.4	Tev BPM Electronics commissioning complete	4/29/05	C								■				
2706	2.2.4.2.12.2	Production Readiness Review	5/25/05	C								■				

Tev BPM
Schedule slip
4-6 wks

M&S Spending (FY04-FY06)



M&S Spending through January 2005		Plan Estimate		FY05	FY05	Inception	Budget Used	
		FY05	Total	Allocation	Obl+RIP	To Date (ITD)	ITD Obl+RIP	YTD Obl+RIP
		FY05	Total	Allocation	Obl+RIP	Obl+RIP	/Total Est	/FY05 Allocation
Run II Upgrades		5,787	17,587	5,677	2,060	12,223	70%	36%
1	Luminosity Upgrades	4,124	13,342	4,232	1,306	9,622	72%	31%
1.1	Protons on Target	401	1,624	399	81	1,111	68%	20%
1.1.1	Slip Stacking	10	416	10	7	381	92%	65%
1.1.2	Pbar Target and Sweeping	11	54	0	-3	12	22%	
1.1.3	MI Upgrades	311	980	320	0	504	51%	0%
1.1.4	Booster-MI Cogging	0	0	0	0	0		
1.1.5	OTR	69	174	69	77	215	123%	112%
1.2	pbar Acceptance	485	1,333	336	151	596	45%	45%
1.2.1	LiLens	99	406	102	96	218	54%	94%
1.2.2	AP2 and DB Acceptance	386	927	234	55	378	41%	23%
1.3	pbar Stacking and Cooling	1,971	5,133	1,721	528	3,620	71%	31%
1.3.1	S&C Task Force	0	0	0	0	0		
1.3.2	Debuncher Cooling	0	0	0	0	0		
1.3.3	Stacktail Upgrade	642	1,491	655	64	756	51%	10%
1.3.4	Recycler Commissioning	227	469	227	35	242	52%	16%
1.3.5	Electron Cooling	795	2,613	521	355	2,237	86%	68%
	AIP	384	1,777	126	272	1,837	103%	
	Non AIP	411	836	395	83	399	48%	
1.3.6	Rapid Transfers	307	560	318	73	386	69%	23%
1.4	Tevatron High Luminosity	1,267	5,161	1,322	547	4,193	81%	41%
1.4.1	Beam Studies and Simulation	0	38	0	0	41	106%	
1.4.2	Active BBC	361	1,395	360	129	607	44%	36%
1.4.3	Increased Helix Separation	381	1,038	406	167	972	94%	41%
1.4.4	Luminosity Leveling	0	0	0	0	0		
1.4.5	Improved Controls and Diagnostics	254	2,147	281	212	2,129	99%	75%
1.4.6	Tevatron Vacuum Improvements	80	234	80	4	197	84%	5%
1.4.7	Tevatron Alignment	191	308	195	35	247	80%	18%
1.6	Management	0	92	454	0	102	111%	0%
2	Reliability Upgrades	1,663	4,245	1,445	753	2,601	61%	52%
2.1	Vulnerability White Paper	783	2,667	697	652	1,478	55%	94%
2.2	Reliability Upgrades	880	1,578	748	101	1,122	71%	14%



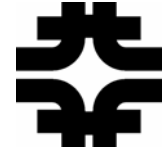
M&S Budget

- Budget guidance including contingency = \$20,946K FY04-06

M & S in Then Yr \$K	FY04	FY05	FY06	Total
Budget Guidance	12,444	7,547	955	20,946

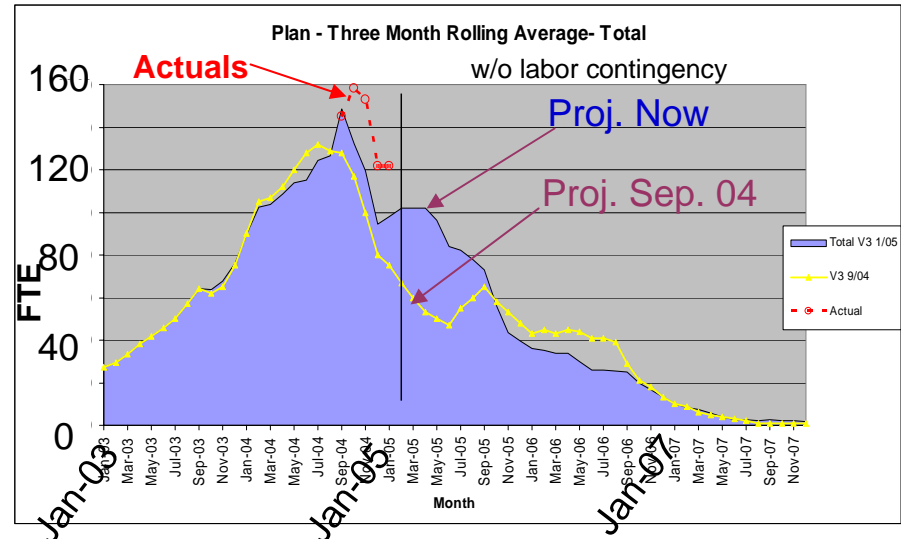
- Contingency is held by Fermilab Directorate and released via Change Request process
- Base estimate = **\$17,587K** (Jan. est.)+\$658K (CRs in process)=\$18,245K
- Est. to complete= \$18,245K - **\$12,223K** = \$6,022K
- Available Contingency= \$20,946K - \$18,245K = \$2,701K
- Currently 45% contingency on estimate to complete

Labor Profile



Base labor profile in FTE estimated from RLS

- FTE=work/0.85
- w/o labor contingency
- Actuals collected from effort reporting in Divisions
 - Follows the estimate trend
- Features in the new estimate
 - The Jan – Aug 05 hump due to slewing + added new scope
 - Slip in Tev BPM, IPM, OTR
 - e-cool commissioning detailed plan Jan. –Sep. 05
 - Transverse dampers for Recycler Jan. – Aug. '05
 - Tev Separators, TEL R&D Dec. '04 – July '05
 - Drop for >Sep. 05
 - De-scope in Tev Separators project
 - Cancelled work on mini-seps.



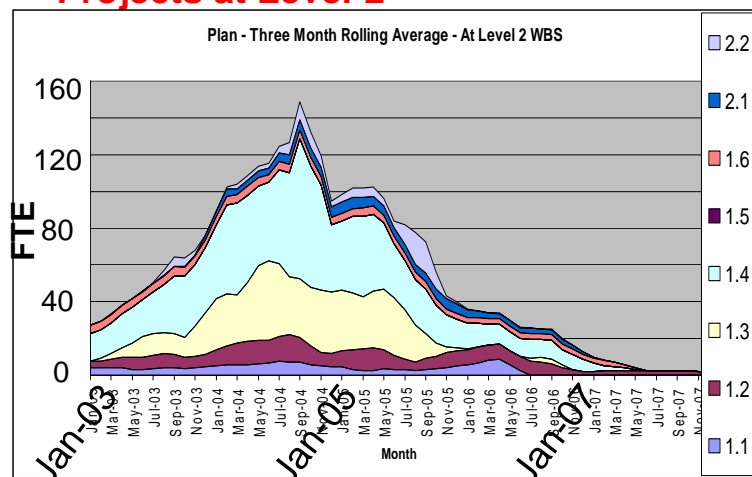
Snap-shot for the month of January 05
Actual vs Estimate

FTE January 2005		Totals	Plan
Run II Upgrades		116.1	96.3
1	Luminosity Upgrades	110.0	88.7
1.1	Protons on Target	11.0	5.4
1.2	pbar Acceptance	10.4	6.4
1.3	pbar Stacking and Cooling	39.8	32.9
1.4	Tevatron High Luminosity	45.6	40.0
1.6	Management	3.2	4.0
2	Reliability Upgrades	6.2	7.6

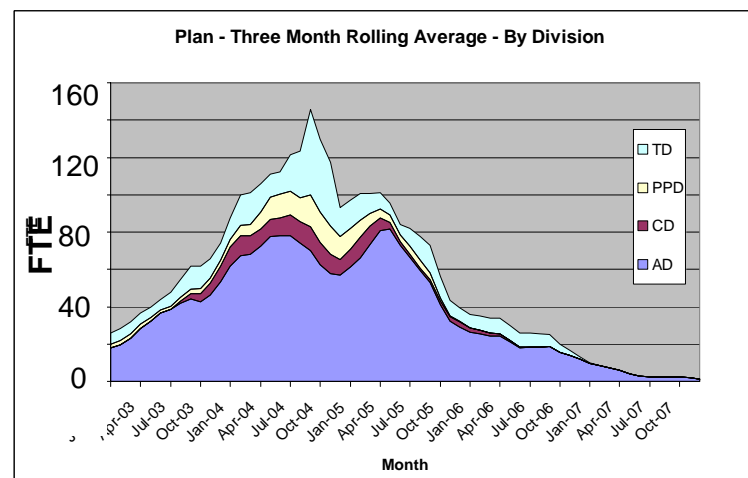


Labor Profile

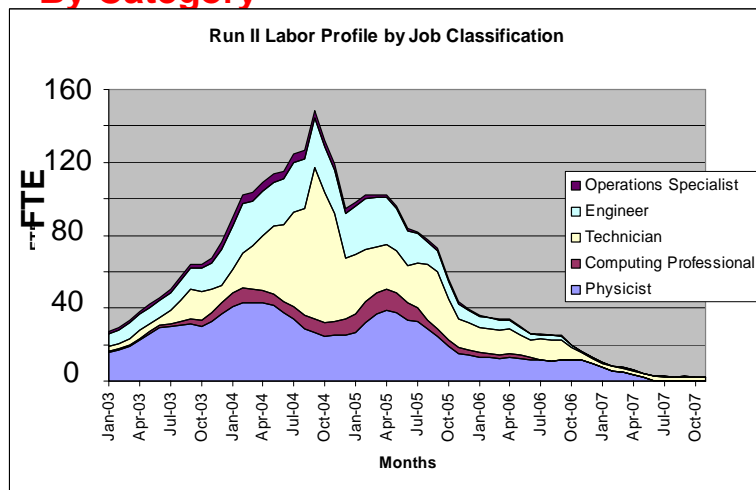
Projects at Level-2



By Division



By Category

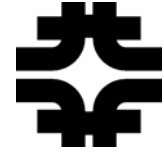


Totals for
categories

Category	FTE Months
All	3302.6
Tech	1060.9
Ops Spec	95.6
Engr	691.0
Comp Prof	217.3
Physicist	1237.6

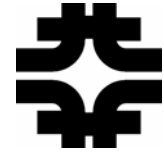


Scope of Work for FY05-09



Scope of Work

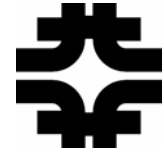
- FY05
 - Continue optimizing slip-stacking (Operations)
 - Complete Tev BPM project
 - Commission 2.5 MHz pbar acceleration
 - Continue improving pbar acceptance & stack rate
 - Improve diagnostics in AP2/DB/D→A
 - Commission electron cooling
 - Continue helix/separators R&D
 - Prepare TEL2, IPM and OTR for installation



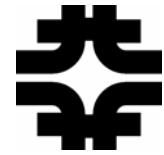
Scope of Work

- FY06
 - Make electron cooling operational
 - Implement stacktail upgrades
 - Continue to improve antiproton acceptance
 - Commission TEL2 into operations
 - Complete MI BPM project
 - Complete BLM project
- FY07
 - Complete antiproton acceptance improvements
 - Complete helix improvements

Schedule and Strategy Update



- Electron cooling equipment installation complete (Feb. 05)
 - Next: Commission electron cooling of pbars at Recycler
 - estimate demo of cooling by September 05
(Tentative '05 shutdown 10/3/05)
start in HEP by end 05 ?
 - Need operating experience with electron cooling before installing the bandwidth upgrade in the Stacktail
 - now scheduled for 06 shutdown
- Mixed source operation (pbars from both Accumulator and Recycler) until e-cooling phased into operation – capitalize on improved reliability
- Phased approach to the Stacktail Upgrade



Phased Approach

Stacktail

- Present
 - $\sim 16E10/\text{hr}$, need to go up to $24E10/\text{hr}$, core $< 250E10$ in the accumulator
- Tank move
 - $\sim 30E10/\text{hr}$ (x2 margin), core $\sim 40\text{--}60E10$, transfer $>$ hourly to Recycler
 - quick to implement and reverse
- Bandwidth upgrade
 - $\sim 40E10/\text{hr}$ (x2 margin), core $\sim 20\text{--}40E10$, transfer \sim half-hourly
 - major shutdown to install and reverse

Accumulator \rightarrow Recycler Transfers

- now: manual, proton tune-up like shot setup, takes < 1 hr
- Summer 05: MI injection dampers, AP1 ramped, no tune-up $\sim 20\text{min}$
- Dec 05: BPM upgrade \rightarrow auto-feedback for next transfer $\sim 2\text{--}3\text{min}$

Sequence for next two phases

- mixed-source operation through 05 : Phase 2 continued
- end 05 (once electron cooling operating in HEP): Tank move \rightarrow Phase 3
- early 06: Bandwidth upgrade ready to install
- bandwidth upgrade installed summer 06 shutdown \rightarrow Phase 4



Luminosity Projections & Risk Analysis

Luminosity Projections



Our plan is to deliver the Design Projection

But, develop an understanding of fallback scenarios

In v3, mixed-source operation and the phased stacktail upgrade allow more natural introduction of key upgrades (e-cooling and Stacktail upgrades) and provide a more robust fall-back position

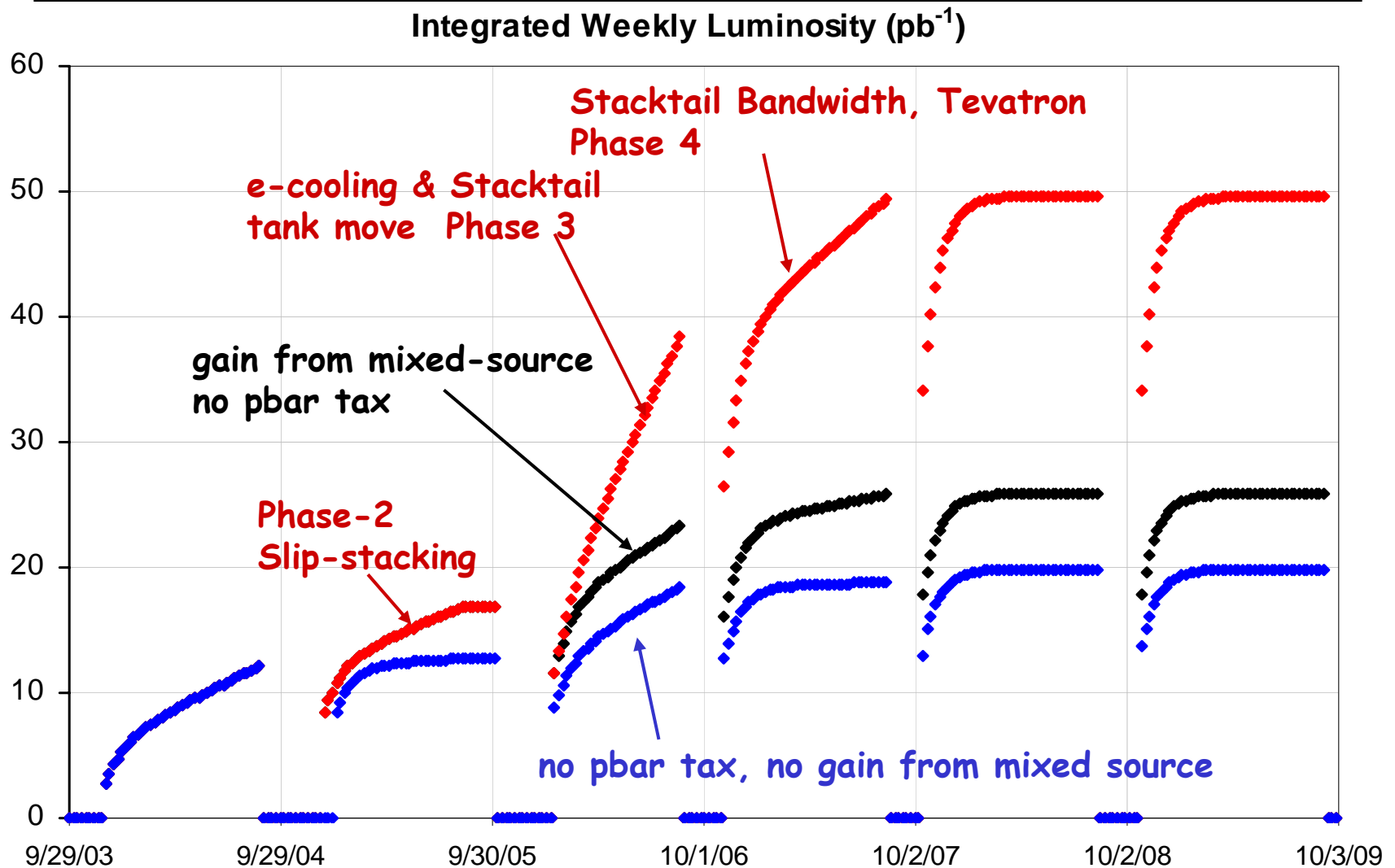
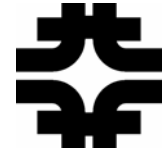
Three Curves

- Design Projection: electron cooling and Stacktail upgrade
- Black Projection: no electron cooling, mixed-source operation beyond 05 (20% gain), Deb→Acc acceptance issues solved
- Blue Projection: no electron cooling, Deb-Acc acceptance only minor improvements and no gain from mixed-source

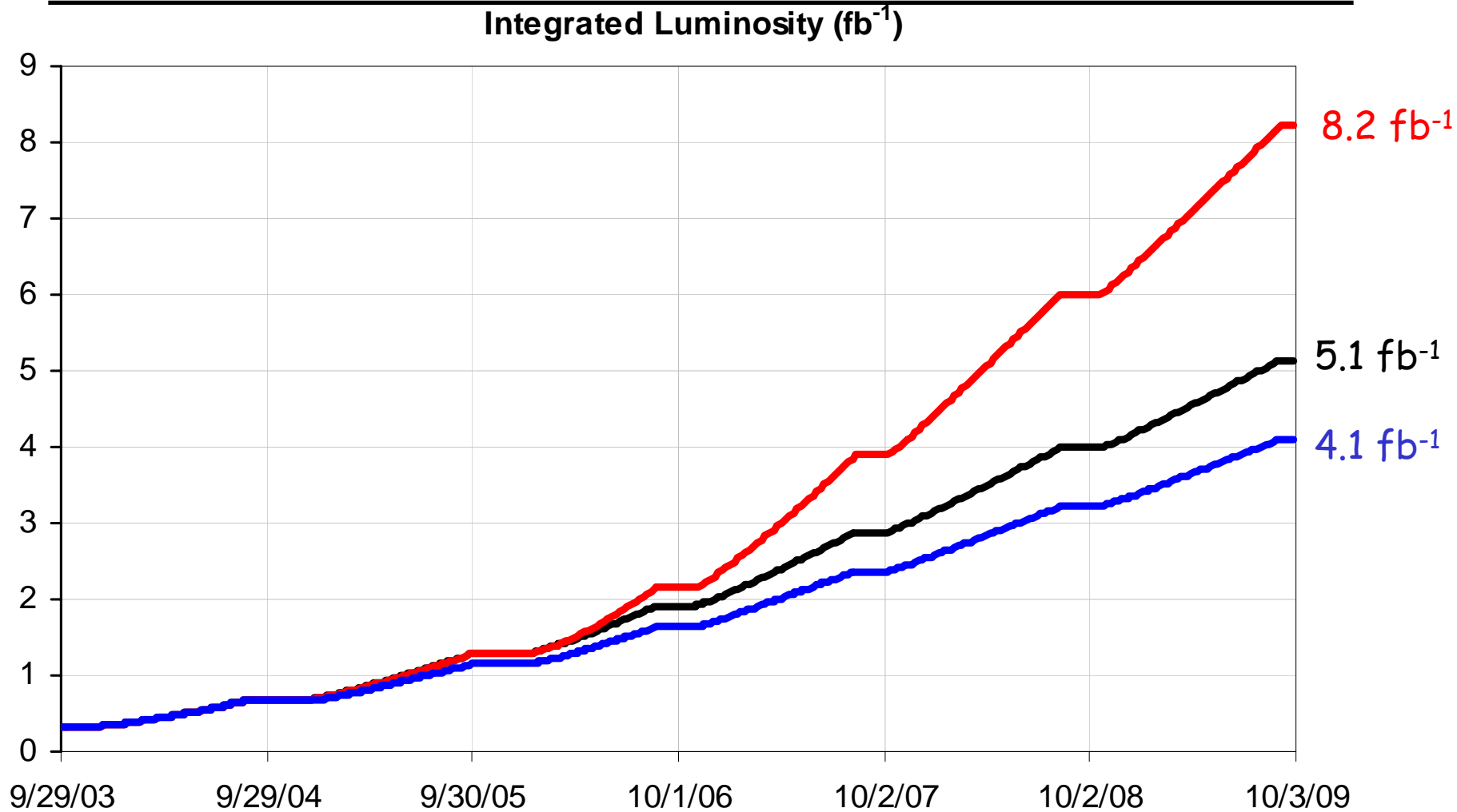
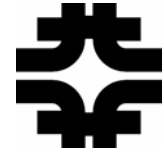
All assume slip stacking and 100 HEP hrs per week average long-term

Latest update: Incorporate the current tentative shutdown schedule for FY05-09

Weekly Luminosity



Integrated Luminosity





Parameters: Design Curve

Phase	2	2	3	4_5	6	
Parameter	FY05 Last 10	Slip Stacking	Recycler Ecool + Stacktail tank FY05 Goal move	Stacktail +Helix	Reliability	Units
Initial Luminosity	98	96	219	284	284	$\times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
Integrated Luminosity per week	19	17	38	50	50	pb^{-1}
Average Store Hours per Week	128	100	100	100	100	Hours
Store Length	21.6	20	20	15	15	Hours
Number of Protons per bunch	240	260	260	270	270	$\times 10^9$
Number of Pbars per bunch	37	42	99	131	131	$\times 10^9$
Zero Stack Stacking Rate	14	24	30	46	46	$\times 10^{10}/\text{hour}$
Average Stacking Rate	8	10	22	39	39	$\times 10^{10}/\text{hour}$
Stack Size transferred	200	201	447	589	589	$\times 10^{10}$
Pbar Production	16	17	21	32	32	$\times 10^{-6}$
Protons on Target	6.1	8	8	8	8	$\times 10^{12}$
Pbar cycle time	2	2	2	2	2	Secs.
Pbar up time fraction	0.74	0.75	1	1	1	
A->R Transfer interval			2.5	0.5	0.5	Hours
A->R Transfer efficiency			90	98	98	%
A->R Transfer Time			0.2	0.05	0.05	Hours

merge

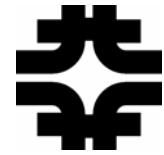
e-cool

Recommendations Score Card



- Recommendations from Feb 04 DOE review and from Sep 04 mini-review
- Compiled in a “recommendations scorecard” – see handout
- Will not go through in detail here ...
- Many items were already on-going; “In-process” ones will be carried out

	Recommendation	Carried out	In Process	As recommended	Similar to Rec'n			Recommendation	Carried out	In Process	As recommended	Similar to Rec'n
Accelerator Physics	AP1		X		X		Instrumentation	I1=AS2		X	X	
	AP2		X		X			I2	X		X	
Proton Source	PS1=AS3	X		X			Cost Estimate	CE1	X		X	
	PS2	X		X			Overall Management	OM1	X			X
	PS3	X		X				OM2=MP1	X		X	
	PS4	X		X			Management Process	MP1=OM2	X		X	
Antiproton Source	AS1	X		X			Planning and Plans	PP1	X		X	
	AS2=I1		X	X				PP2	X		X	
	AS3=PS1	X		X				PP3	X		X	
	AS4	X		X				PP4	X		X	
	AS5	X		X			From September '04 Minireview					
	AS6	X		X			Technical	1=AS1	X		X	
Tevatron	T1	X		X				2		X		X
	T2		X	X				3		X		X
	T3	X		X				4		X		X
	T4		X		X			5	X			X
	T5		X		X							
	T6	X		X			Cost, Schedule &					
	T7		X	X			Management	1	X		X	



Summary

- The Fermilab Run II Campaign is going well!
- Major Run II upgrades milestones for phase-2 met
- Recycler operating well and contributing to luminosity
- Run II upgrades are 62% complete; Projects making good technical progress and on track for improving luminosity
- e-cooling of pbars still the biggest technical challenge and we should know better by September 2005
 - Interim technical progress review in May 2005
- Tests for stacktail cooling upgrades in Fall 2005
- The design luminosity projection is still $\sim 8 \text{ fb}^{-1}$ thru 2009
- New phasing along with improved reliability and mixed-source operation make the fall-back scenarios more robust, $> 4 \text{ fb}^{-1}$